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## ROCK-CUT SURFACES IN THE DESERT RANGES<sup>1</sup>

SIDNEY PAIGE

In an article entitled "The Geographical Cycle in an Arid Climate"<sup>2</sup> William M. Davis has presented a physiographic analysis of the ultimate results of erosion in an arid region. His conclusions are based partly on the work of Passarge and others and partly upon his own deductions. The system erected is in its larger features so complete that those who follow in interpreting particular physiographic products need only assign such features to their proper place in the larger system already established. That the following conclusions, therefore, were reached independently and seem to fit perfectly with the system outlined by Davis is an additional corroboration of the soundness of his deductions, and the excuse for their publication must rest upon the wish expressed by Davis "that the scheme of the arid cycle may lead to the detection of many facts concerning the evolution of land forms in desert regions that have thus far escaped notice."

G. K. Gilbert<sup>3</sup> stated in describing the Basin Range system of the West: "Between them [the ranges] are valleys floored by the detritus from the mountains which conceals their depth and leaves to the imagination to picture the full proportions of ranges of which the crests alone are visible, while the bases are buried beneath the débris from the summits." It is with the processes by which gravel sheets engulf mountain masses and with certain erosional features associated with such accumulations that the following notes have to do. An explanation is sought for a number of rock-cut benches or surfaces, occurring at the edges of Quaternary gravel sheets in the Silver City quadrangle, New Mexico. The facts will be presented first; what is believed to be an analogous

<sup>1</sup> Published with the permission of the Director of the U.S. Geological Survey.

<sup>2</sup> *Journal of Geology*, XIII, No. 5, July-August, 1905.

<sup>3</sup> *Report upon Geographic and Geologic Surveys West of the 100th Meridian in Charge of Lieutenant George William Wheeler*, Vol. III, p. 22.

case will be described next; and certain conclusions more or less hypothetical will be stated last.

Well-marked though dissected rock-cut benches occur in a number of areas within the Silver City quadrangle. Their relations to the highlands, out of which they have been carved, and to

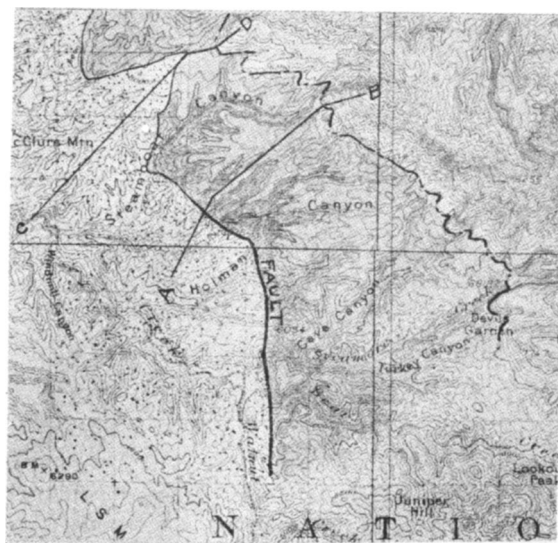


FIG. 1.—Vertical scale double the horizontal. 1 square=1 mile

the gravel deposits, to which they contributed material, are shown in Figs. 1, 2, 3, and 4. The shaded portions show the areas in which the rock-cut dissected surfaces are found. Dotted areas indicated gravel. The most important features of these benches are: first, that they slope gently upward from the edge of the gravel with a profile concave upward and terminate abruptly against a mountain

flank of considerable steepness; second, that they present a remarkable evenness of surface, when viewed from a sufficient distance to reduce the prominence of recent dissection; and third, that they truncate rock structure without any decided evidence of selection.

As indicated in Fig. 1, the boundary between the gravel and the bench of hard rock may be divided into two parts; one where erosion has revealed a depositional unconformity, the other where faulting has disturbed this normal relation. The slope of the bench

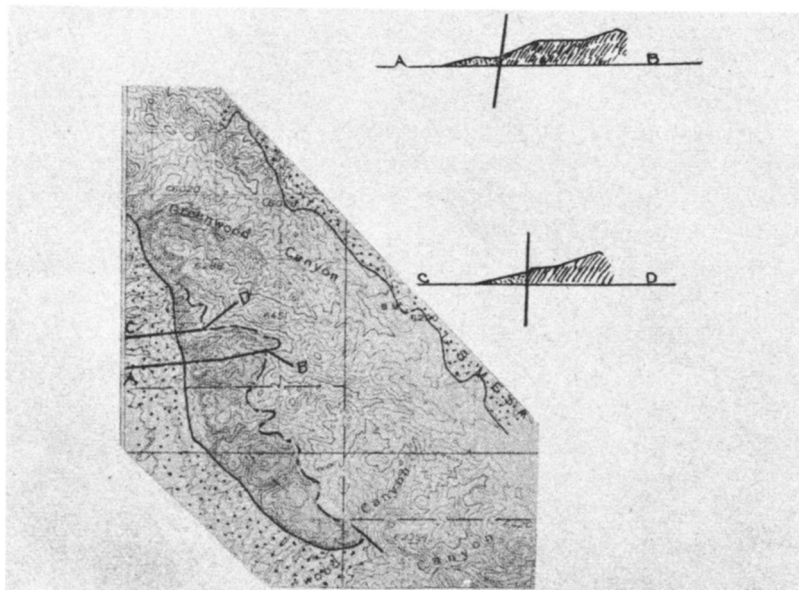


FIG. 2.—Vertical scale double the horizontal. 1 square = 1 mile

in continuous with the slope of the gravel sheet, and is astonishingly regular from the edge of the gravel to the mountain front. Notable is the irregular depositional boundary in the northern portion where the gravel rises gently upon the bench nearly to the foot of the mountain scarp; notable also the straight boundary where faulting has altered this relation.

It seems that the conditions here are peculiarly fortunate and diagnostic. If the faulting had not occurred, it is doubtful whether the bench would have been exposed. Even the northwestern portion would probably have been more completely covered. As it

happens, the gravel sheet is shown reaching almost to the mountain core upon a sloping rock-cut bench. That the bench contributed to the sheet and that the sheet gradually crept mountainward over the bench seems plausible. A fault has raised the bench,

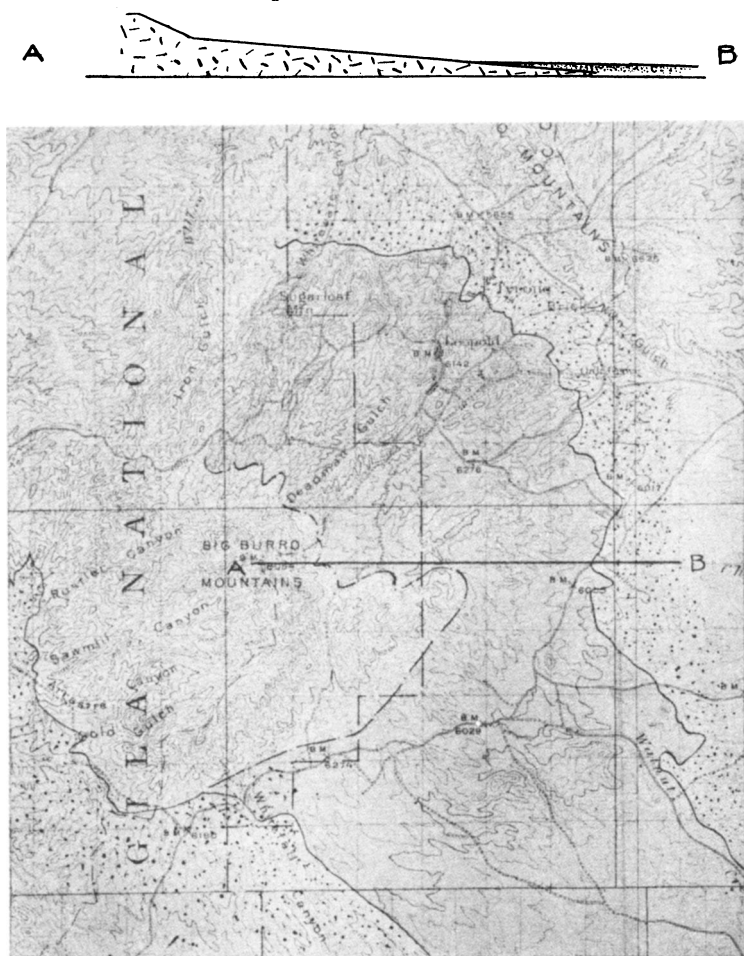


FIG. 3.—Vertical scale double the horizontal. 1 square = 1 mile

which, by virtue of its elevated position, has been stripped by erosion of a considerable part of the gravel deposit from the area above the fault line. Patches remaining are taken to show that the bench was formerly gravel capped throughout.

In Fig. 2 the northeast and southwest sides of a low mountain range are shown with the Pleistocene gravel boundaries. Attention is called first to the proximity of the northeastern boundary to the crest line of the range, second, to the relatively straight boundary of the western gravels along whose entire course there is believed to exist a fault. The bench here exposed (though severely dissected by sharp canyons) is interpreted as the old floor upon which gravel

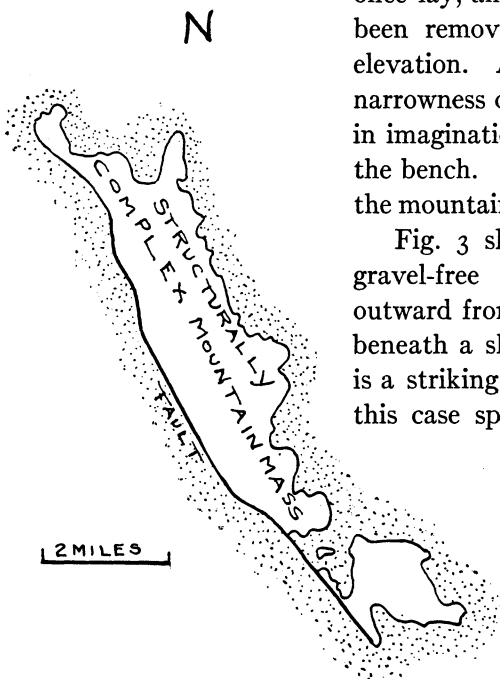


FIG. 4

once lay, and here again the gravel has been removed because of its superior elevation. An interesting point is the narrowness of the mountain remnant if, in imagination, we restore the gravel to the bench. It shows clearly how nearly the mountain range escaped destruction.

Fig. 3 shows a mountain core and gravel-free rock bench which slopes outward from the mountains and passes beneath a sheet of gravel. The bench is a striking physiographic feature. In this case special attention is called to the southeastern portion where the gravel has been cleanly swept from a portion of the bench. Although straight boundaries between gravel-covered and gravel-free portions of the bench are not observed, there are geologic reasons

for believing that there has been uplift, a movement sufficient to initiate removal of the gravel sheet and dissection of the bench.

Fig. 4 shows a mountain mass with its surrounding gravel sheet. Note the straight fault contact on the southeastern side. The figure is somewhat analogous to Fig. 2 but the remains of any bench that may have existed is nearly or quite obliterated by recent cutting. The figure serves, however, to show, because of the fault,

that the original remnant of the mountain left by the gravel encroachment was probably narrower even than at present.

It should be stated that the gravels here referred to are the borders of very extensive desert deposits, stretching for miles to the south and west and are, or have been, the encroaching tongues of the great sheets, the tentacles, so to speak, by which gravel accumulation incorporates a mountain mass.

The scene for a moment may now well be shifted to "the broad expanse of plain and mountain in southwestern Arizona and western Sonora (Mexico), stretching from the Sierra Madre to the Gulf of California and lying between Gila and Yaqui rivers."<sup>1</sup>

At first sight the Sonoran district appears to be one of half-buried mountains, with broad alluvial plains rising far up their flanks, and so strong is this impression on one fresh from humid lands that he finds it difficult to trust his senses when he perceives that much of the valley-plain area is not alluvium, but planed rock similar to or identical with that constituting the mountains. To the student of geomorphy this is the striking characteristic of the Sonoran region—the mountains rise from the plains, but both mountain and plain (in large part) are carved out of the same rocks. The valley interiors and the lower lowlands are, indeed, built of torrent-laid débris, yet most of the valley area carries but a veneer of alluvium, so thin that it may be shifted by a single great storm. Classed by surface, one-fifth of the area of the Sonoran district, outside of the Sierra and its foothills, is mountainous, four-fifths plain; but of the plain something like one-half, or two-fifths of the entire area, is planed rock, leaving only a like fraction of thick alluvium.

Thus is clearly set forth by Dr. W. J. McGee the product of a long cycle of erosion.

A short digression is necessary here in order to define the term sheet flood, the force of which agent is of importance in the present discussion. In the words of W. J. McGee,

Under certain conditions, sand-laden water flowing over an erodable plain tends at first to divide into parallel streams like those of pure water on an indestructible surface, yet, since the streams formed in this way at once begin to scour and overload themselves and thus check their own flow, this tendency is soon counteracted and the water is distributed again; so that the ultimate tendency is toward movement in a more or less uniform film or sheet.

<sup>1</sup> McGee, W. J., "Sheet Flood Erosion," *Bull. Geol. Soc. Amer.*, VIII, February 13, 1897, pp. 87-112.

Regarding the efficacy of sheet floods to erode the land surface W. J. McGee says:<sup>1</sup>

The inference from the character of the sheet flood is consonant with the necessary inference from the character of the base level surface. Over dozens or scores of square miles in carefully examined localities, hard rocks like those of the mountains, and with no sign of decomposition, are planed almost as smooth as the subsoil by the plowshare, with nothing either in configuration or in covering to indicate that streams have flowed over them, and extended consideration has yielded no other suggestion as to the eroding agent than that found also in analogy with the observed sheet flood.

Thus in unequivocal terms the rock-cut plains are assigned to an origin by sheet-flood erosion. The question naturally arises in the mind of the reader, Was there a stage in the past history of the region during which such plains might have been formed by a process approaching in kind that of peneplanation? Again quoting W. J. McGee:<sup>2</sup>

The fourth inference is that the massif [he refers here to an uplifted folded area] produced in this way stood at moderate altitude for a long period including approximately the Eocene and the earlier half of the Miocene, that a large part of its volume was degraded; that the surface was planed to an *approximate base level*,<sup>3</sup> relieved by ridges and masses of the monadnock and catoclin types, usually of harder layers but sometimes marking broad divides, and that during this vast period the drainage basins were outlined and developed. It is deemed probable that during much or all of this period the precipitation was greater than now, so that the district throughout was one of degradation and so that the drainage basins were of the normal dendritic type veined by rivers occupying broad yet essentially V-shaped valleys; and it is considered probable also that the basin-limiting Sierras were less rugged than now.

The meaning of the above paragraph is a little ambiguous—the reference to “approximate base level” does not fit in with “rivers occupying broad yet essentially V-shaped valleys.” One cannot reach a definite conclusion, therefore, as to whether the rock-planed surfaces, referred to above, were dependent upon this stage for their beginnings. But considering the language used in describing the rock-planation, one is inclined to infer that W. J. McGee regards sheet-flood erosions as the primary process in such planation.

The foregoing description of the Sonoran benches, it seems to the writer, applies to the rock-cut surfaces of the Silver City region,

<sup>1</sup> *Op. cit.*, p. 108.

<sup>2</sup> *Op. cit.*, p. 95.

<sup>3</sup> *Underscored* by the writer of this paper.



provided the plane surface now scarred by recent dissection be assumed restored. Post-Quaternary faulting (probably an effect of more widespread uplift than is indicated by relative movements of blocks) is a sufficient cause for the dissection which has occurred.

A hypothesis to explain the features described above may now be presented. The intention is not to follow a process throughout all its possible variations, but to suggest an idea which may serve as a nucleus for future elaboration. All the processes by which rock-cut benches may be formed need not be enumerated. The facts in this case point obviously to the encroachment of an accumulating gravel sheet upon a highland area. The end result now achieved may perhaps be attained as follows.

An area (of which the Basin Range system is an example) may be so warped by regional uplift that inclosed basins are formed. A climate is postulated of such aridity that permanent lakes will not rise to such altitudes as to overflow the rims of the inclosed basins. Such basins are favorable for the rapid sub-aerial accumulation of detrital matter.

Active erosion within this system now becomes regulated by an all important factor: *progressive burial by alluviation of low-lying areas*. It is conceived that a central portion retains its original topographic sculpture because of complete oversweep of débris. Each succeeding portion of topography before it is buried will have been more reduced, will have been more softened in that it has suffered a longer period of exposure than the portion immediately preceding it.

*The rising edge of the gravel sheet acts as an effective control below which erosion cannot take place.* The result is unavoidable if the time factor and the factor of area are sufficiently large. *A process tending toward leveling with respect to the gravel sheet will proceed.* But the gravel sheet has been gradually rising; therefore, *the leveled surface is a sloping plain thinly veneered with gravel.*

A second process, it is believed, plays an important part in this result. The feature which leads to the recognition of the process is the abrupt change of gradient at the mountainward border of the rock-cut plain. A consideration of the character of the stream channels which debouch upon the rock-cut plain may give a clue

to the origin of this oversteepening of topographic gradient. Aggrading streams flow out upon fans and fans have a cross-section concave upward. Such a cross-section implies that from time to time the stream will flow against the mountain wall and initiate lateral cutting. It may be argued in opposition to this view that it will build up here as elsewhere and prevent any persistent lateral cutting at a definite level. This objection may be answered by pointing out that a desert level of great expanse is a feature of great stability, far more permanent than the local filling at the side of a fan. This filling may be swept out and renewed many times before the general level of the desert is raised an appreciable amount by accumulation. This process then, viz., lateral cutting, combined with that outlined in the preceding paragraph, seems to account for all the conditions that need explanation. Both must have worked from the beginning of the cycle.

#### CONCLUSIONS

The considerations which have been outlined above suggest the following tentative conclusions: (a) Processes of erosion within an inclosed basin system in an arid climate tend ultimately to produce surfaces of very low relief about the borders of the gravel sheet which accumulate within the basin. (b) The gradual rising of the gravel filling implies an equally gradual rising of the local base level. (c) The surface resulting from such a shifting system tends ultimately to take the form of a sloping planated surface, most perfect at its mountainward side and progressively more irregular valleyward beneath the gravel cover. (d) Interstream erosion, lateral cutting at edges of accumulating fans, and progressive burial of low-lying areas are the factors which govern the formation of the rock-cut surface. (e) The abnormally steep mountain flank against which the rock-cut plain abuts is considered the normal product of the three processes mentioned above. (f) Sheet-flood erosion is considered a *result* of the rock-cut plains and not a *cause* of the plains as hypothesized by W. J. McGee. (g) The old planated surfaces near Silver City, though now dissected because of readjustments of drainage due to faulting, are regarded as examples of the type described in the Sonoran district.